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**Original research article**

# THE ROLE OF COUNTERMOVEMENT IN THE MANIFESTATION OF EXPLOSIVE LEG STRENGTH IN VERTICAL JUMPS

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**Abstract**. *In order to explain the role of countermovement in the manifestation of explosive strength in vertical jumps performed with and without countermovement, the difference between the components of explosive strength in those jumps was analyzed on a sample of 44 elite Serbian cadet age volleyball players. The sample of tests consisted of eight components of explosive strength manifested in vertical jumps: jump height, maximal vertical speed, duration of the concentric jump phase, maximal force, maximal relative force, the ratio between maximal force and duration of the concentric jump phase, maximal power during the concentric jump phase and the average power during the concentric jump phase. The results have shown that all the components of explosive strength are significantly greater in the case of the countermovement jump in comparison to the squat jump, except for maximal power during the concentric jump phase. The greatest differences at the numeric level are noted in terms of the force/time ratio (3415 N/s or 59.9 %), then in average power in the concentric jump phase (611 W or 38.3 %), as well as in the duration of the concentric jump phase (0.076 s or 26.7 %) and jump height (7.9 cm or 23.5 %). Nonetheless, differences are also noted in maximal relative force (0.33 N or 14.1 %) and in maximal force (215 N or 13.4 %). The least significant differences are noted in maximal vertical speed (0.09 m/s or 3.5 %). In the case of maximal power during the concentric jump phase ($P_{max}$), no significant differences were noted. The ensuing differences are ascribed to the role of the countermovement, which produces the changes in muscle activation, and initiates the stretch-shortening cycle of the muscle, as well as the occurrence of the 'elastic potentiation' of the muscles in the case of the countermovement jump, and thus increased muscle work.*

**Key words**: *countermovement, explosive leg strength, vertical jump, volleyball players.*

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## INTRODUCTION

Explosive strength is defined as an individual ability of the neuro-muscular system's ability to manifest strain in the shortest period of time (Herodek, 2006). It is usually manifested in vertical jumps, but it is also an important characteristic in many sports activities which require the performance of maximal muscle force in as short a period of time as possible. The explosive strength manifested in vertical jumps increases the height which the athlete can achieve, which can be useful in achieving top results in sport (Häkkinen, 1993).

In order to evaluate the explosive strength of the lower extremities, the vertical jump is often used. The vertical jump can be found in a variety of different sports and contains a large number of components (jump height, contact time, vertical speed, peak power, amortization power, extension power, impulse of force, etc.), which require specific abilities that are not necessarily and mutually related. The vertical jump can take the form of a one-legged and two-legged vertical takeoff (Ham, Knez, & Young, 2007).

Explosive strength is manifested during two phases: the eccentric (stretch) and concentric (shortening). The concentric phase is almost immediately linked to previous muscle extension (Zatsiorsky, 1995). Muscle function during the stretch and shortening cycle (SSC) is classified either as slow (contact with the surface is longer than 0,25 seconds) or quick (contact with the surface is shorter than 0,25 seconds) (Schmidtbleicher, 1992). We can also refer to them as slow and quick plyometrics. Vertical jumps with a countermovement (Countermovement jump - CMJ) and without countermovement (Squat jump - SJ) are all examples of slow plyometrics, while on the other hand, the depth jump (DJ) represents an example of quick plyometrics. In both cases, the pre-activation enables maximal force and work which the muscles can produce during the concentric phase. In the case of slow plyometrics, the stretching phase is significantly slower, thus the contribution of the stretching reflex is significantly smaller when compared to quick plyometrics (Finni, Komi, & Lukkariniemi, 1998). It was also noted that the muscle fiber stretching phase in the case of slow plyometrics is greater when compared to quick plyometrics (Finni, Ikegaw, Lepola, & Komi, 2001).

It has been proven that participants achieve a higher jump height in the case of the CMJ, where the participant first assumes an upright position, and then begins his downward movement prior to takeoff, rather than straight from the SJ, where the initial position of the participant is a semi-squat, without a countermovement phase (van Ingen Schenau, Bobbert, & de Haan, 1997).

It is believed that the height of the vertical jump significantly correlates with maximal force in relation to body mass. In numerous studies, the test used to measure the vertical jump is based on a simple measurement of the height of the vertical jump of the athlete. However, in order to evaluate the different parameters of the vertical jump, a variety of tests can be applied, including maximal leg strength, the maximal extent of force production, the ability of the athlete to increase force, the activating stretching and shortening cycle during the squat prior to the performance of the jump itself, the ability of the athlete to produce maximal mechanical force, and the ability of the athlete to coordinate movements which are constituent parts of the jumps (Kraemer & Newton, 1994).

Modern diagnostic procedures enable the objective monitoring of a large number of parameters which evaluate the components of explosive strength. For a detailed analysis of the growth in force, maximal mechanical force and the ability to activate the stretching and shortening cycle, a force plate needed. However, some measurements can be recorded with less sophisticated equipment.

The aim of this study was to determine the differences between the components of explosive strength in vertical jumps with and without a countermovement, so as to explain the role of the countermovement in the manifestation of explosive strength in these jumps. The main hypothesis of this study is that all the components of the countermovement jump will be significantly higher compared to the squat jump.

## THE METHOD

### The sample of participants

The sample of participants numbered 44 volleyball players (Age=16±1 years; BH =184.5 ±7.69 cm; BM=69.8±8.14 kg), all members of Serbian elite cadet volleyball club teams: *Crvena Zvezda*, *Zeleznicar* and *Roda* from Belgrade and *Obrenovac* from Obrenovac. The basic criteria for the selection were the following: all of the participants had to be 16 years old (±12 months); all of the participants had to have trained volleyball for a period of four to six years; that they would all be tested under the same conditions and that they were all healthy. All subjects provided written informed consent to participate. This study was approved by the ethics committee of the University of Nis and was performed in accordance with the Declaration of Helsinki.

### The sample of measuring instruments

Explosive strength was evaluated based on two tests for the vertical jump: the squat jump (SJ) and countermovement jump (CMJ) (A description and the protocol of the tests was provided by Bosco, C.[1]). The following components were measured for both jumps:

1. Jump height [Hmax (cm)],
2. Maximal vertical speed [Vmax (m/s)],
3. Duration of the concentric jump phase [Tcon (s)],
4. Maximal force [Fmax (N)],
5. Maximal relative force [Fmax/BM],
6. The ratio between maximal force and duration of the concentric phase [Fmax/Tcon (N/s)],
7. Maximal power during the concentric jump phase [Pmax (W)] and
8. Average power during the concentric jump phase [Pavg (W)].

The participants were tested in laboratory conditions, with the help of a force plate (AMTI, Inc., Newton), with an acquisition frequency of 1000 Hz., through a standardized procedure on the force plate. Prior to the testing itself, a practical presentation of the test jumps was given, and the participants were allowed to perform a series of practice jumps.

For the needs of this study, the body height of the participants was measured [BH (cm)], following the protocol of the International Biological Program (Weiner & Lourie, 1981), while body mass [BM (N)] was measured on the force plate, for the purpose of calculating the maximal relative force. Based on the values of body mass presented in newtons (N), the values were calculated in kilograms (kg) for the purpose of calculating the nutritional status (BMI) of the participants.

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[1] Bosco Ergojump System (Byomedic, S.C.P., Barcelona, Spain).

### The statistical methods of data processing

In order to analyze the statistical data and distribution of the results for both vertical jumps, descriptive statistical procedures were used, and the following parameters were calculated: arithmetic means (Mean); minimum achieved result (Min.); maximal achieved result (Max.); the range of the minimum and maximal result (Range); standard deviation (Std.dev.); coefficient of variation (Coef.Var.); skewness (Skew.) and kurtosis (Kurt.). In order to determine the differences between the parameters of the two vertical jumps (with and without a countermovement), a one-way analysis of variance at the univariate level (one-way ANOVA) was performed. The data was processed using the STATISTICA 7, (StatSoft, Inc., Tulsa, OK) statistical package.

## THE RESULTS

Tables 1. and 2. show the descriptive statistical parameters of the components of the two vertical jumps. By analyzing them, based on the values of skewness (Skew.) and kurtosis (Kurt.) of the distribution curve, we can conclude that the results of all the parameters of the vertical jump components have a normal distribution. This is the basic precondition for any multivariate and univariate methods of determining the differences between the parameters of the components of two vertical jumps to be used in further statistical analysis. The variation coefficients of individual parameters range within the normal values, and thus confirm the homogeneity of the sample of cadet volleyball players, except for the variable of the ratio between force and duration of concentric jump phase ($F_{max}/T_{con}$) in the case of the CMJ, where the coefficient of the variation is high.

**Table 1** The descriptive parameters of the squat jump (SJ)

| Variable | N | Mean | Min. | Max. | Range | Std.Dev. | Coef.Var. | Skew. | Kurt. |
|---|---|---|---|---|---|---|---|---|---|
| BH (cm) | 44 | 184.5 | 165.6 | 199.3 | 33.7 | 7.69 | 4.17 | -0.52 | -0.05 |
| BM (kg) | 44 | 69.8 | 54.0 | 88.0 | 34.0 | 8.14 | 11.66 | 0.03 | -0.53 |
| BM (N) | 44 | 685 | 530 | 863 | 333 | 79.82 | 11.66 | 0.03 | -0.53 |
| $H_{max}$ (cm) | 44 | 33.6 | 21.5 | 44.0 | 22.5 | 5.11 | 15.23 | -0.14 | -0.55 |
| $V_{max}$ (m/s) | 44 | 2.55 | 2.04 | 2.93 | 0.88 | 0.20 | 7.78 | -0.31 | -0.36 |
| $T_{con}$ (s) | 44 | 0.285 | 0.228 | 0.356 | 0.128 | 0.03 | 11.57 | 0.40 | -0.49 |
| $F_{max}$ (N) | 44 | 1603 | 1193 | 2092 | 899 | 221 | 13.76 | 0.23 | -0.31 |
| $F_{max}/T_{con}$ (N/s) | 44 | 5704 | 3452 | 8375 | 4924 | 1085 | 19.01 | 0.25 | -0.08 |
| $F_{max}$/BM | 44 | 2.34 | 1.96 | 2.66 | 0.70 | 0.18 | 7.71 | -0.27 | -0.76 |
| $P_{max}$ (W) | 44 | 3375 | 2200 | 4966 | 2765 | 674 | 19.99 | 0.44 | -0.11 |
| $P_{avg}$ (W) | 44 | 1595 | 1044 | 2447 | 1403 | 332 | 20.86 | 0.57 | -0.11 |

Legend: N – number of participants; Mean – arithmetic mean; Min. – minimum result; Max. – maximal result; Range – range of results; Std.Dev. – standard deviation of arithmetic mean; Coef.Var. – coefficient of variance; Skew. – skewness of the distribution curvature of the results; Kurt. – kurtosis of the distribution curvature of the results.

**Table 2** The descriptive parameters of the countermovement jump (CMJ)

| Variable | N | Mean | Min. | Max. | Range | Std.Dev. | Coef.Var. | Skew. | Kurt. |
|---|---|---|---|---|---|---|---|---|---|
| BH (cm) | 44 | 184.5 | 165.6 | 199.3 | 33.7 | 7.69 | 4.17 | -0.52 | -0.05 |
| BM (kg) | 44 | 69.3 | 53.0 | 86.1 | 33.1 | 8.23 | 11.87 | 0.02 | -0.59 |
| BM (N) | 44 | 680 | 520 | 844 | 324 | 80.70 | 11.87 | 0.02 | -0.59 |
| $H_{max}$ (cm) | 44 | 41.5 | 27.4 | 53.1 | 25.7 | 5.61 | 13.51 | -0.16 | 0.23 |
| $V_{max}$ (m/s) | 44 | 2.64 | 2.07 | 3.01 | 0.95 | 0.19 | 7.36 | -0.65 | 1.14 |
| $T_{con}$ (s) | 44 | 0.209 | 0.147 | 0.302 | 0.155 | 0.04 | 18.30 | 0.86 | 0.11 |
| $F_{max}$ (N) | 44 | 1818 | 1100 | 2620 | 1520 | 310 | 17.06 | 0.21 | 0.56 |
| $F_{max}/T_{con}$ (N/s) | 44 | 9119 | 3642 | 15539 | 11897 | 2765 | 30.32 | 0.69 | 0.56 |
| $F_{max}$/BM | 44 | 2.67 | 1.83 | 3.38 | 1.55 | 0.30 | 11.05 | -0.35 | 1.05 |
| $P_{max}$ (W) | 44 | 3584 | 1967 | 5156 | 3189 | 703 | 19.6 | -0.19 | -0.17 |
| $P_{avg}$ (W) | 44 | 2206 | 1071 | 3246 | 2175 | 430 | 19.5 | -0.33 | 0.61 |

Legend: N – number of participants; Mean – arithmetic mean; Min. – minimum result; Max. – maximal result; Range – range of results; Std.Dev. – standard deviation of arithmetic mean; Coef.Var. – coefficient of variance; Skew. – skewness of the distribution curvature of the results; Kurt. – kurtosis of the distribution curvature of the results.

In terms of average values, the body height of the volleyball players was 184.5 cm, body mass was 69.3 kg, and thus based on these measurements we can conclude that the sample of volleyball players were of normal weight, based on the nourishment criteria of the Body Mass Index (BMI=20.36) (Cole, Bellizzi, Flegal, & Dietz, 2000). The values of the parameters of the components of explosive strength are significantly greater than the values of boys of the same age or older, who do not actively take part in sports activities (Markovic, Mirkov, Knezevic, & Jaric, 2013).

Table 3. shows the results of a one-way univariate analysis of variance, based on which we can conclude that there is a statistically significant difference between the SJ and the CMJ in all the monitored components of explosive strength, except for maximal power of the concentric jump phase ($P_{max}$). At the univariate level, this significance is noted at the $p \leq 0.00$ level for all the individual parameters, except for maximal vertical speed, where the significance is at the level of $p \leq 0.05$. The greatest differences are noted in terms of the duration of the concentric jump phase ($SJ_{Tcon}$=0.285; $CMJ_{Tcon}$=0.209), whose F value is 101.2, then in the ratio between maximal force and duration of concentric jump phase ($F_{max}/T_{con}$; F=58.16), average power during the concentric jump phase ($P_{avg}$; F=55.74) and jump height ($H_{max}$; F=48.59), and to a lesser extent in the case of the maximal relative force ($F_{max}$/BM; F=39.95), and least of all for maximal force ($F_{max}$; F=14.15) and maximal vertical speed ($V_{max}$; F=4.74). In the case of maximal power during the concentric jump phase ($P_{max}$) no significant differences were noted, but they were clearly at the numeric level. Greatest differences at the numeric level were noted in terms of the force/time ratio (3415 N/s), then in average power in concentric jump phase (611 W), as well as in duration of the concentric jump phase (0.076 s) and jump height (7.9 cm). No differences were noted in maximal relative force (0.33 N) and in maximal force (215 N). The least significant difference was noted in maximal vertical speed (0.09 m/s).

**Table 3** The univariate differences between the parameters of SJ and CMJ

| Variable | Mean SJ | Mean CMJ | Diff. | Diff. (%) | F (1, 86) | p |
|---|---|---|---|---|---|---|
| $H_{max}$ (cm) | 33.6 | 41.5 | 7.9 | 23.5 | 48.59 | **0.000** |
| $V_{max}$ (m/s) | 2.55 | 2.64 | 0.09 | 3.5 | 4.74 | **0.032** |
| $T_{con}$ (s) | 0.285 | 0.209 | -0.076 | -26.7 | 101.02 | **0.000** |
| $F_{max}$ (N) | 1603 | 1818 | 215 | 13.4 | 14.15 | **0.000** |
| $F_{max}/T_{con}$ (N/s) | 5704 | 9119 | 3415 | 59.9 | 58.16 | **0.000** |
| $F_{max}$/BM | 2.34 | 2.67 | 0.33 | 14.1 | 39.95 | **0.000** |
| $P_{max}$ (W) | 3375 | 3584 | 209 | 6.2 | 2.02 | 0.158 |
| $P_{avg}$ (W) | 1595 | 2206 | 611 | 38.3 | 55.74 | **0.000** |

Legend: Mean SJ – arithmetic mean of the SJ; Mean CMJ – arithmetic mean of the CMJ;
Diff (cm) – difference between means in cm; Diff. (%) – difference between means in percent;
F – value of the coefficient of the F – test for testing the significance of the difference;
df 1, df 2 – degrees of freedom; p – coefficient of the difference of arithmetic means.

## DISCUSSION

Based on the analysis of the obtained results, we can clearly note a significant difference between the parameters of the SJ and the CMJ, with the conclusion that all the parameters of the CMJ are considerably greater. The most significant differences are noted in the terms of the force/time ratio (59.9 %), then in average power in concentric jump phase (38.3 %), as well as in duration of the concentric jump phase (26.7 %) and jump height (23.5 %). Nonetheless, differences are also noted in maximal relative force (14.1 %) and in maximal force (13.4 %). The least differences were noted in maximal vertical speed (3.5 %). These results agree with the published differences in other studies which dealt with this problem (Finni, Komi, & Lepola, 2000; Bobbert, Gerritsen, Litjens, & Van Soest, 1996; Gollhofer, Strojnik, Rapp, & Schweizer, 1992; Häkkinen, Komi, & Kauhanen, 1986).

The noted differences are ascribed to certain components and mechanisms found in the performance of the CMJ, which significantly contribute to the increase of both jump height, and other jump parameters when compared to the SJ. The authors of previous studies ascribed the differences between the SJ and the CMJ to changes in the muscle activation, the presence of the stretch and shortening cycle (SSC), as well as the occurrence of the 'elastic potentiation' of muscles in the CMJ.

During the SSC, prior to contact with the surface, the muscle is pre-activated based on the extent of the expected load. The pre-activated muscle begins its eccentric contraction immediately after the initial contact with the surface, when the muscle-tendon unit (MTU) extends and receives signals for the activation of the nervous system. The eccentric phase was then followed, without much delay, by a concentric contraction. At the same time, the SSC plays an important function in the movement, to reduce the unnecessary delays in the relation between force and time (F/T), matching the level of force during the pre-activation with the necessary level of the expected eccentric load, to perform a final concentric action, in relation to the appropriate isolated concentric contractions (Komi & Gollhofer, 1997).

With the onset of pre-activation, the activation of the muscles in the eccentric phase increases during the performance of the CMJ and thus contributes to the achievement of the maximal muscle work (MMR) during the concentric phase. The high level of muscle activation during the eccentric phase of the CMJ does not include the presence of differences in the activation of muscles during the concentric phase between the SJ and the

CMJ, which has been proven by many studies (Walshe, Wilson, & Ettema, 1998; Bobbert et al., 1996; Häkkinen et al., 1986). The analysis of the parameters of the SJ and the CMJ in the study of McBride, McCaulley, & Cormie (2008), indicates that differences in the level of activation of the agonist muscles during the concentric phase is not statistically significant, which confirms that the absence of pre-activation under the conditions of the performance of the SJ does not lead to a decrease in muscle activation during the concentric phase, when compared to the CMJ. However, the present significant difference in jump height, maximal force during the concentric phase and the maximal duration of the concentric phase, along with the fact that the eccentric phase is not present during the performance of the SJ confirms that the improved performance during the concentric phase of the CMJ can be ascribed to muscle activation during the eccentric phase.

The explanation for achieving the MMR with the application of the CMJ is that it offers the muscles an opportunity to gradually develop force. For example, the leg extensors need 300-500 ms to achieve 90% of the maximal force (Bobbert & van Ingen Schenau, 1990; Komi, 1979). The role of elastic elements in a sequence of contractile elements is also important in the achievement of maximal force. During the performance of the CMJ, active muscles are stretched and absorb energy, and part of that energy is temporarily preserved in sequences of elastic elements, which will be activated during the concentric phase. This mechanism is also referred to as 'elastic potentiation' (Komi, 1992). This indicates the ability of MTU to store and release elastic energy. It has been proven that the elastic energy stored in the muscle tendons significantly contributes to the effectiveness of the CMJ (Henry, Ellerby, & Marsh, 2005). On the other hand, during the performance of the SJ, through the absence of an eccentric phase, and thus the elastic potentiation, muscle stimulation during the concentric phase is at a submaximal level.

Thus, if we were to claim that the active state of the concentric contraction occurs at the point of force development, then one part of the force is developed submaximally, which further means that the produced work is submaximal (Bobbert et al., 1996; Chapman, Caldwell, & Selbie, 1985). From the previous conclusions we can see that the concentric contraction cannot develop maximal muscle activation. On the other hand, during the initial phase of the CMJ, the head, arms and torso gain angular speed, which has a negative value. By increasing the moment of torsion in the hip joint, the angular velocity gains a positive value, so that angular velocity can gradually increase so that in the end its value finally becomes positive (van Ingen Schenau et al., 1997). Thus, in the. case of the CMJ, force and speed gradually develop, so that during the concentric contraction submaximal values can be produced, unlike in the case of the SJ, where the angular velocity during the active state of the concentric contraction equals zero (van Ingen Schenau et al., 1997). Thus, less muscle work is produced during the SJ in comparison to the CMJ (Bobbert et al., 1996), and thus we can explain the increased values of the concentric contraction, which can refer to jump height, the duration of the concentric contraction, maximal force, relative maximal force, maximal vertical speed and average power, in favor of the CMJ.

In addition to the aforementioned, we should refer to the fact that stretching of an active muscle changes the characteristics of the contractile apparatus and activates the spinal reflex (Dietz, Schmidtbleicher, & Noth, 1978), as well as the longer latent reaction (Jones & Watt, 1971), which help in the increase of muscle stimulation during the concentric phase up to the supramaximal level, while the force produced in isolated muscles can increase as a result of stretching, and whose values could be up to two times greater than the isometric force (Ettema, Huijing, van Ingen Schenau, & De Haan, 1990).

When performing a movement, muscle length changes, and these changes in length influence muscle force. The force-length relation is explained through the optimum interaction between actin and myosin filaments, to which we ascribe the active component of muscle force. In the case of most skeletal muscles, the increase in muscle force occurs during smaller changes in muscle length, and we conclude that with the increase of muscle length, muscle force grows as well. The feature of muscles to increases their force with an increase in length, is the result of reflex activities which additionally increase the extent of the muscle activities during extended length. Thanks to this feature, the muscle behaves like a spring – its stretching brings about an increase in force.

Even though we believe that muscle hypertrophy improves the effectiveness of the vertical jump, it is important to mention that any kind of increase in mass, without an increase in strength, can have a negative influence on the effect. Maximal achieved height during the jumps is a very demanding activity where the contraction of muscle fibers is dominant, which is why it is important to avoid any excessive hypertrophy of slow muscle fibers, especially in the case of jumps where contact with the surface is short-lived. The capacity of the produced force during the maximal contraction was determined by the surface of the cross-section and activation abilities of the relevant muscles (van Soest & Bobbert, 1993).

## CONCLUSION

The experimental data which were gathered and presented in this study undoubtedly indicate that the parameters of the jump height, the duration of the concentric contraction, maximal force, the relative maximal force, maximal speed and average speed have greater values in the case of the CMJ, in comparison to the SJ. One of the main causes of these results is the fact that the amount of produced work during the CMJ is significantly greater than in the case of the SJ. Based on the studies of Bobbert et al. (1996), several important factors in the mechanism of development of maximal force during the performance of the CMJ should be viewed, which were described in this study. We should especially emphasize that, even though the formation of energy in the elastic muscle elements contributes to the development of maximal muscle force, a much greater role is ascribed to the mechanisms, that is, the dynamics of the development of maximal strength, where the muscles are fully activated during the CMJ, and thus, for that reason can produce more work than in the case of the SJ.

One of the most important contributors which lead to the complete muscle activation in the case of the CMJ is angular velocity, which is a consequence of the rotation of segments of the head, arms and torso and the increase in angular positive acceleration, as well as the consequence of the moment of torsion caused by the activation of the extensor in the hip joint, which leads to complete muscle activation. Finally, we can conclude that, if all the previously mentioned mechanisms take part in muscle activation, the greatest influence on the development of muscle strength during the concentric contraction is exerted by the full activation of the muscles during the eccentric contraction, which leads to an increase in the overall work during the CMJ. The conclusions that could be drawn from the results of this study may be essential for volleyball coaches, who could consider the most effective models of plyometric training, based on a fundamental patterns of movement, technique, scope, intensity and frequency of the sport of volleyball. Due to changes in muscle activation, the selection of exercises for strength and power training in volleyball should be recognized in specific movements, instead of simple and uniform strength training. Improvements in efficiency, especially within the muscle activation implies an increase in co-ordination and is an important tool to increase explosive power (Semmler, Steege, Kornatz, & Enoka, 2000). The specificity of the schemes of movement in volleyball rebounds, which is reflected in the activation of whole muscle, as well as the efficiency of the stretch reflex and SSC, has its own specifics in relation to the type of movement. As a result, the role of an agonist, antagonist, and the stabilizer muscles must be carefully considered. These functional roles could be changed from single to multi-joint movement, as well as the speed of their performance (Zajac & Gordon, 1989). In volleyball, in which specific movements are based on complex multi-joint movements, especially those that require high rate of force and speed performance, the transfer of training effects is likely to be higher using multi-joint movements, which have similar kinetic and kinematic characteristics.

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# ULOGA POČUČNJA U MANIFESTACIJI EKSPLOZIVNE SNAGE NOGU U VERTIKALNIM SKOKOVIMA

*Sa ciljem da objasni uloga počučnja u manifestaciji eksplozivne snage u vertikalnim skokovima iz počučnja i čučnja, izračunata je razlika između komponenti eksplozivne snage u tim skokovima na uzorku 44 vrhunskih srpskih odbojkaša kadetskog uzrasta (AGE=16+1 year; BH=184.5+7.69 cm; BM=69.8+8.14 kg). Uzorak testova je činilo 8 komponenti eksplozivne snage iskazanih u vertikalnim skokovima: Visina skoka, Vertikalna brzina, Vreme koncentrične faze, Maksimalna sila, Maksimalna relativna sila, Odnos maksimalne sile i vremena koncentrične faze, Maksimalna snaga u koncentričnoj fazi i Prosečna snaga u koncentričnoj fazi. Rezultati su pokazali da su najveće razlike u korist vertikalnog skoka sa zamahom evidentirane kod vremena koncentrične faze (Tcon)(0.076 s; 26.7%), kod odnosa sile i vremena (Fmax/Tcon)(3415 N/s; 59.9%), prosečne snage u koncentričnoj fazi (Pavg)(611 W; 38.3%) i visine odskoka (Hmax)(7.9 cm; 23.5%), nešto manje kod maksimalne relativne sile (Fmax/TM)(0.33; 14.1%), a najmanje kod maksimalne sile (Fmax)(215 N; 13.4%) i maksimalne vertikalne brzine (Vmax)(0.09 m/s; 3.5%). Kod maksimalne snage u koncentričnoj fazi (Pmax) nisu zabeležene značajne razlike, ali su one evidentne na numeričkom nivou. Nastale razlike se pripisuju ulozi počučnja, koji produkuje promene u aktivaciji mišića, pokreće ciklus skraćivanja i izduživanja (SSC), kao i pojavu „elastične potencijacije“ mišića kod CMJ, a samim tim i veći mišićni rad.*

Ključne reči: *počučanj, eksplozivna snaga nogu, vertikalni skok, mišićni rad, odbojkaši.*